K-12 Teachers to Teach Computer Science in USA

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New curriculum reform across the United States requires teacher educators to rapidly develop and implement professional development (PD) for K-12 teachers, newly assigned to teach computer science (CS). One of the many inherent challenges in providing valuable PD is knowing what it is that novice CS teachers most need.

Keywords: computer science education ; teacher education ; professional development (PD) ; K-12 teacher

1. Introduction

As the digital information age defining this century rapidly unfolds, so do the immediate professional development (PD) needs of K-12 teachers. Nowhere, perhaps, is this more disruptive than in the rapidly emerging domain of computer science (CS) instruction [1]. Many states across the United States are struggling with how to best respond to education reform calls for increasing the quantity and quality of CS education, spanning the entire K-12 grade bands [2]. Wyoming, like many other states, is initiating CS teaching deliverables across its school districts. These changes are being influenced through multi-year, multi-agency, state-government-backed initiatives that are still being constructed, even as CS is made available to public-school students across the state [3]. A vital component of this Wyoming initiative is preparing the state's K-12 schoolteachers to implement CS concepts in their classrooms.

Few existing in-service teachers were ever formally trained on how to teach CS during their undergraduate teacher preparation programs. In response, some states have relied on professional computer scientists as content experts to lead CS instruction in schools [4]. In contrast, Wyoming certified teachers across all disciplines of content are charged with this task. Such a scenario leaves wide open the question of how to best support teachers in teaching CS concepts for which they have little to no experience in teaching. Naturally, one way for teachers to prepare for this challenge is by completing a K-12 CS endorsement program as a PD experience at an institution of higher education. In Wyoming, in cooperation with the state government's Professional Teaching Standards Board (PTSB), several institutions of higher education have created endorsement programs designed to fulfill the new requirements for teachers to become a certified Wyoming K-12 teacher by earning a K-12 CS endorsement. Such an approach to creating highly qualified teachers allows teachers the opportunity to teach K-12 CS immediately [5].

Northwest College (NWC), a two-year college located in the rural Rocky Mountain west, offers one such CS endorsement program. NWC's program consists of 15 semester credits offered over the course of three to four semesters and is delivered using a cohort model [6]. The first NWC K-12 CS Endorsement program began in June 2020, with 13 certified teachers graduating in May and July of 2021. Of these 13 teachers, 7 went on to teach CS in K-12 schools the Fall of 2021; all 7 of these were surveyed for this research study.

Given how new these educational reforms are, there exists an open question as to how to best prepare teachers to teach CS. In particular, it is unclear from the existing literature base precisely what it is that new CS teachers most need. It is to this end that this research study was designed. Because CS education is not yet a fixture in Wyoming, the experiences of the teachers who have completed the endorsement program and subsequently taught CS informs the NWC faculty development team as they continue to iteratively modify the curriculum and structure of the K-12 CS endorsement program to better serve the immediate needs of Wyoming's new cadre of K-12 teachers assigned to teach CS.

2. K-12 Teachers' Perceptions and Experiences in Teaching Computer Science

This topic builds on a process presented extensively elsewhere in "Identifying implementation challenges for a new computer science curriculum in rural western regions of the United States" [7]. However, the researchers have a different focus on K-12 teachers' perceptions and experiences. Because implementation of universal K-12 CS education in Wyoming begins in the Fall of 2022, the PD curriculum is evolving over time and is informed by the participants. The

researchers delved into this topic, believing that the expectations and experiences of the first classroom teachers to earn CS endorsements should become an integral part of the CS outcomes and can help construct the practices that Wyoming will ultimately use to shape K-12 CS education in the future. Yadav et al. [8] discussed the current trend of educating non-computer scientists to teach CS and focused on these teachers' perspectives as they deliver the CS curriculum. Their findings are important to this research study because Wyoming has accepted a similar model of training STEM and non-STEM teachers alike to implement CS education. Yadav and colleagues [8] cite the teachers' lack of adequate CS training and the isolation they feel from often working alone as challenges. In Wyoming, allowing teachers to work in cohorts may help them develop a community of other non-STEM CS teachers to mitigate this challenge.

The Wyoming Department of Education [9] has adopted seven performance standards for CS. These standards are broader than coding and computational thinking (CT) alone [10]. The literature on CS and CT in K-12 classrooms addresses this breadth and also the teachers' role in K-12 CS education. Astrachan and Briggs [11] discussed the importance of the creative and intellectual aspects of CS, while ChanLin [12], Borowczak and Burrows [10], and Lee and colleagues [13] focused on teachers' perceptions of the importance of integrating CS into their classrooms. Goode [14] studied the role of teachers in teaching CS. She explored the applicability of PD models and asserted that curriculum alone is not enough: teachers require well-constructed PD and support to teach CS effectively. In this way, she separated and related the knowledge of CS from the practice of teaching CT. In follow-up research, Goode, Margolis, and Chapman [15] set up the connection between educational research related to PD for CS and CT teachers, describing the Exploring Computer Science PD model. The state's Department of Education (WDE) CS Standards [16] reflect a similar breadth, not limited to CT and CS, but teaching collaboration and inclusivity as well. Collaboration and inclusivity were initially addressed by using a cohort model for the NWC K-12 CS endorsement program, by forming learning communities within cohort participants.

Researchers in different areas of the United States have studied different PD models and programming environments in relation to their effectiveness in preparing in-service teachers to deliver K-12 CS education. Gray and colleagues [17] described statewide PD models for teacher preparation for CS teaching in Alabama. The project, entitled CS4Alabama, is a year-long PD using a teacher leader model of mentoring new CS teachers. Continuing along this line of research, Lee's team [13] made connections between established STEM subject areas and CS integration, describing a model for in-service teacher PD that is valuable for integrating CS by making connections between STEM fields and other areas of study. Similarly, Borowczak and Burrows [10] studied NetLogo as a platform for teacher PD for integrating CS into the curriculum. The results revealed that classroom applications were limited to topics addressed in the PD. Connecting this research to teachers' perceptions before and after teaching may illuminate some ideas for broadening classroom applications.

In summary, the goal of the endorsement program is targeting is two-fold. First, the program should prepare teachers for classroom experiences. Second, the PD experience will be improved by using teachers' feedback. This approach should bridge the distance between pre-teaching and post-teaching experiences as part of the distance to the connection between PD and learning outcomes.

3. Contextualization of Research

3.1. How Is Quality PD Created?

"A bridge, like professional development, is a critical link between where one is, and where one wants to be" [18] (p. 2). In the matter of Wyoming's K-12 CS initiative, the bridge is the distance between content and performance standards [16] and learning outcomes. The specific span of the bridge addressed in this research study is the link between completing the PD and teaching CS.

The researchers studied the literature as a foundation for developing NWC's K-12 CS endorsement program. This PD was designed based upon Content and Performance Standards, enumerated by Wyoming Department of Education [16], which, in turn, was written using the overarching goals set forth by the Wyoming legislature [19]. Specifically, in 2020, a committee was empaneled by the WDE and, in 2021, published a report identifying seven CS practices; the NWC K-12 CS endorsement program was based on these practices. These practices are enumerated by the Wyoming Department of Education [16]. Through this process, the design of NWC's K-12 CS endorsement program is connected to Wyoming's newly developed K-12 CS standards. Additionally, the expectations and the design of the PD are consistent with the seven principles of excellent professional development identified and enumerated by Loucks-Horsley [18]. A main focus of this research is to create effective, consistently deliverable PD to provide Wyoming K-12 teachers with experiences that will facilitate the delivery of K-12 CS education in all Wyoming schools, as described below.

A major structural element of effective PD is instructional scaffolding. Instructional scaffolding is a structured approach to education, in which support is provided to help students master foundational tasks based on student experiences and knowledge. Belland [20] lists four key features of instructional scaffolding: first, temporary support is provided as students are engaging with problems. Second, scaffolding needs to lead to skill gain, such that students can function independently in the future; third, scaffolding builds on what students already know; and fourth, students meaningfully participate in a target task to gain understanding of what success at the task means. As described by Kleickmann et al. [21], instructional scaffolding addresses the fact that higher-level skills (here, CS, CT and coding) are impossible to teach without first teaching the basics (here, filing systems, shortcut keys, and other elements specific to different platforms). Each step requires instructional scaffolding in order to prepare participants for the next element of the PD, which is consistent with Belland's [20] and Kleickmann et al.'s [21] findings. These authors address the need to create an instructional scaffold to systematically build on foundational skills in order to facilitate learning new skills with no knowledge gaps.

The seminal work on professional development for K-12 teachers, "Designing Professional Development for Teachers of Science and Mathematics", by Susan Loucks-Horsley and colleagues [22], has served as a foundational work for designing PD since the first edition was published over two decades ago (1999). The late Loucks-Horsley highlighted seven principles common to effective PD experiences for STEM teachers, revolving around clarity related to teaching, broadening opportunities for teachers, mirroring/modeling instructional methods for the teachers to use with their students, encouraging teachers to form learning communities with other STEM teachers, developing leadership among teachers, teaching or linking across the curriculum, and continually assessing the professional development process [22].

To be sure, high-quality PD is best based on a foundation of structure and content. Based on the academic literature, Burrows and colleagues [23] cite six best practices for developing successful PD. These practices are enumerated in **Table 1**.

Table 1. Best practices for developing successful PD.

Best Practice for Successful PD	Reference
Improvement of content knowledge, pedagogy, and dispositions	**Crippen [24]; Loucks-Horsley, Love, Stiles, Mudry & Hewson [25] ; Penuel et al. [26]; Zozakiewicz & Rodriguez [27]**
Creation of instructional materials	**Burrows, Briener, Keiner, & Behm [28]; Jackson & Ash [29]; Stolk, DeJong, Bulte & Pilot [30]**
Use of authentic science and inquiry practices	**Marshall & Alston [31]; Spuck [32]**
Consideration of socioscientific issues	**Zeidler [33]**
Iterative cycles of use and reflection	**Penuel et al. [26]**
Partnership development and leverage	**Burrows, 2015 [34]**

Darling-Hammond and colleagues [35] state that many PD experiences are ineffective in supporting changes when connected to teacher practices and student learning. To identify the features of effective professional development, they reviewed 35 research studies to identify the features of effective PD. They identified that most effective PDs share seven features. They are content focused, incorporate active learning, support collaboration, use models and modeling of effective practice, provide coaching and expert support, offer opportunities for feedback and reflection, and are of sustained duration.

Foundational misconceptions can create barriers to successful PD. One such misconception surrounding the term *model* was uncovered by Reynolds, Burrows, and Borowczak [36]. In 2018, these authors conducted a two-week-long STEM PD for in-service teachers. One goal of the PD was to help participants use computer science modeling in their classrooms. Although instruction on modeling was presented throughout the PD, follow-up discourse among participants revealed that they did not move past their prior conception of the term model. When participants heard this term, their attention was directed to their previous understanding of *model* and away from the meaning of model as a CS concept. Because of this fundamental misunderstanding, the CS modeling that was taught had no schema to attach to in the participants' views, which led to the disconnect. This unexpected misconception highlights how important fundamental concepts can be and how future learning can be impeded by a lack of foundational understanding by participants in a PD.

3.2. Literature Gap

In Wyoming the State's Department of Education outlines scripted content and performance standards for guidance and direction to school districts; in turn, the districts are charged with the responsibility for implementing education for all students with fidelity. Student learning is assessed by measuring learning outcomes, with certified teachers serving as the conduit between standards, curriculum implementation, and student learning outcomes. In this way, PD can be imagined to be serving as one span of the bridge between standards and learning outcomes.

Because Wyoming's education initiative is still being implemented, it is crucial that the effectiveness of the K-12 CS endorsement program is continually evaluated to achieve maximum efficiency. By relating teachers' perceptions before and after they use this material to teach, faculty development teams should be able to deliver more effective curricula based upon input received at critical junctions between PD and learning outcomes.

The lack of connection between PD and learning outcomes has been identified as a gap in the literature. As articulated by Hewson [37] and reaffirmed by Burrows [34]: "Although PD among STEM teachers has been studied and connected to national standards, a gap exists in studying PD in a systematic manner, especially in regard to the connection between PD and learning outcomes". By collecting teachers' perceptions of the effectiveness of the endorsement program before teaching and comparing the results to their perceptions after they used the material to teach, researchers can better focus on this critical junction. This focus contributes to understanding this span of the gap in the literature.

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